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(54) **SYSTEM, METHOD, AND COMPUTER-READABLE MEDIUM FOR USER EQUIPMENT DECISION-MAKING CRITERIA FOR CONNECTIVITY AND HANDOVER**

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H04W 72/00 (2009.01)
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CPC *H04W 36/24* (2013.01); *H04W 88/06* (2013.01)
USPC **455/432.2**; 455/436

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USPC 370/331-334, 311; 455/436-444, 455/432.2, 432.3, 574

See application file for complete search history.

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(57) **ABSTRACT**

A system, method, and computer-readable medium are provided for decision-making criteria in a multi-mode, multi-radio user equipment to choose which radio network to use for connectivity and handover. Decision making depends on a number of different criteria: a user profile that specifies one or more user preference connectivity attributes, available applications of the user equipment, a service subscription of a user associated with the user equipment, a battery monitor of the user equipment, a respective link metrics indicator for each of the plurality of access networks, and application support capabilities of the plurality of access networks.

17 Claims, 5 Drawing Sheets

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| Feature | Home WLAN good Cellular good | Home WLAN good Cellular bad | Around Town No WLAN Cellular good | Hot Spot WLAN good Cellular good | HotSpot WLAN good (room) Cellular good | HotSpot WLAN good (home) Cellular good (room) |
|------------------|------------------------------|-----------------------------|-----------------------------------|----------------------------------|--|---|
| Emergency call | Cellular | WLAN | Cellular | Cellular | Cellular | Cellular |
| VoIP | WLAN | WLAN | CS Voice | WLAN | CS Voice | WLAN |
| Presence | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| Push to Talk | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| Multicast | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| Video conference | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| Voice call (CS) | VoIP | VoIP | Cellular | VoIP | Cellular | VoIP |
| Email - push | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| Email - pull | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| Web - http | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| File download | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| Podcasting | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |
| RSS | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |

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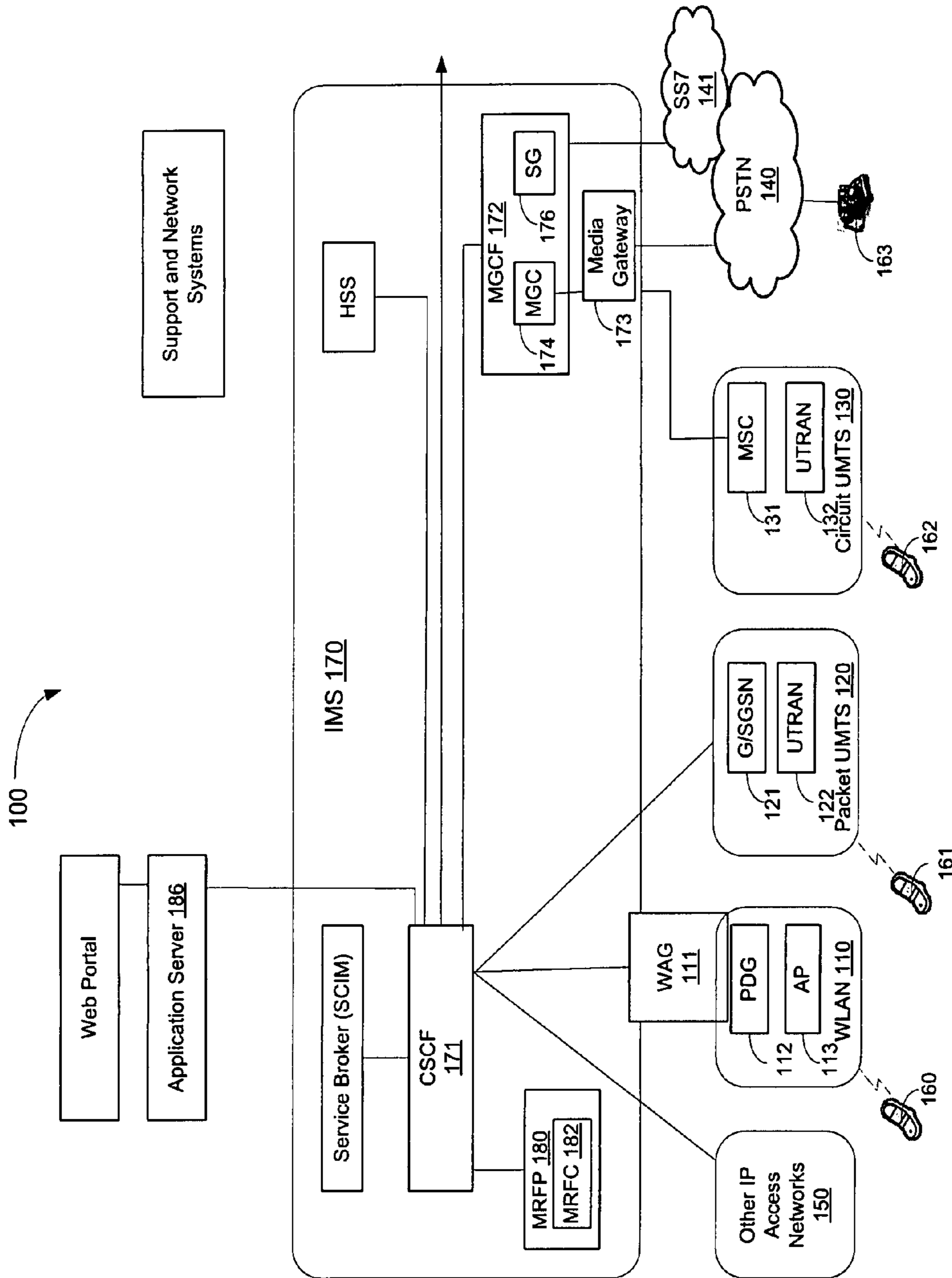


Figure 1

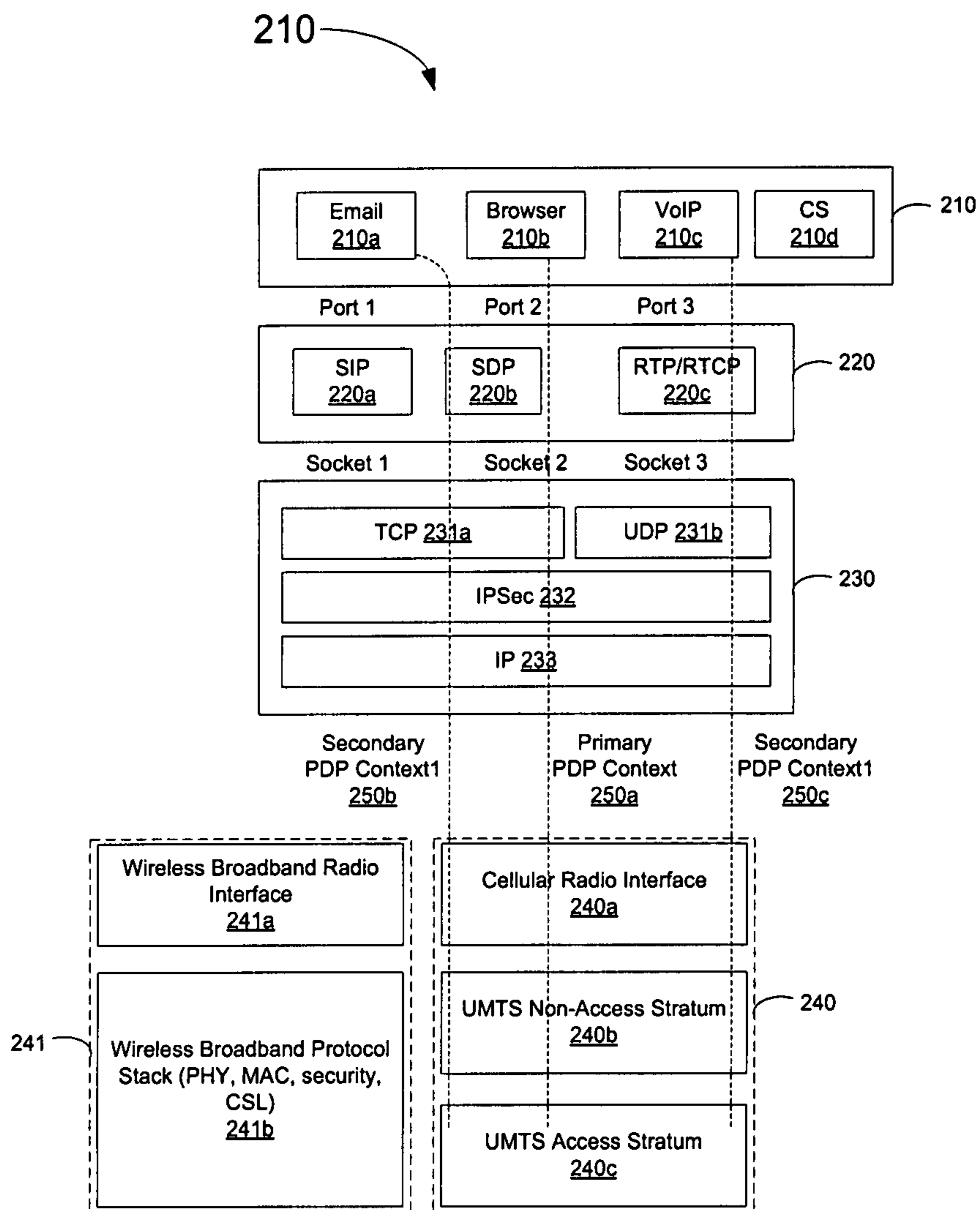


Figure 2

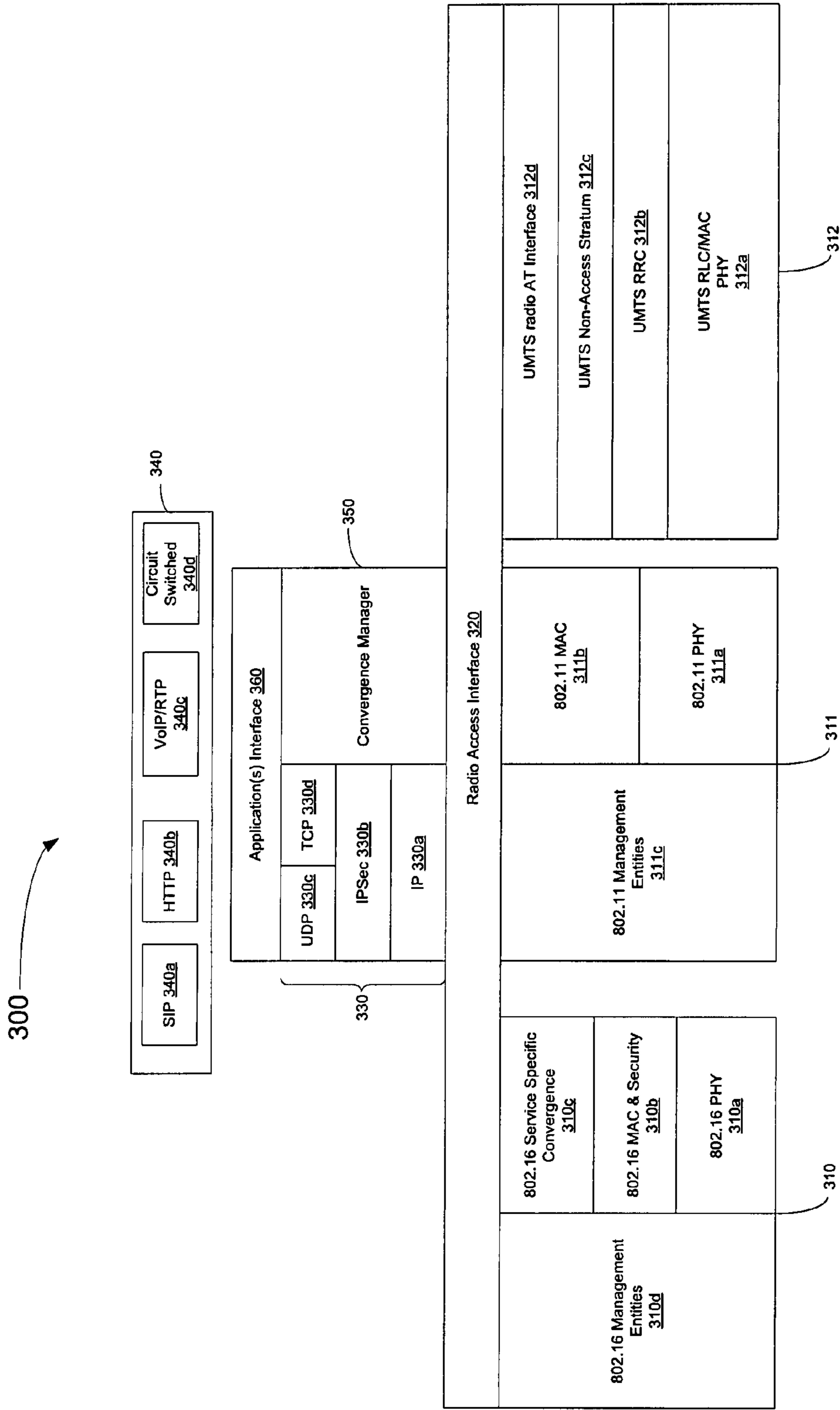


Figure 3

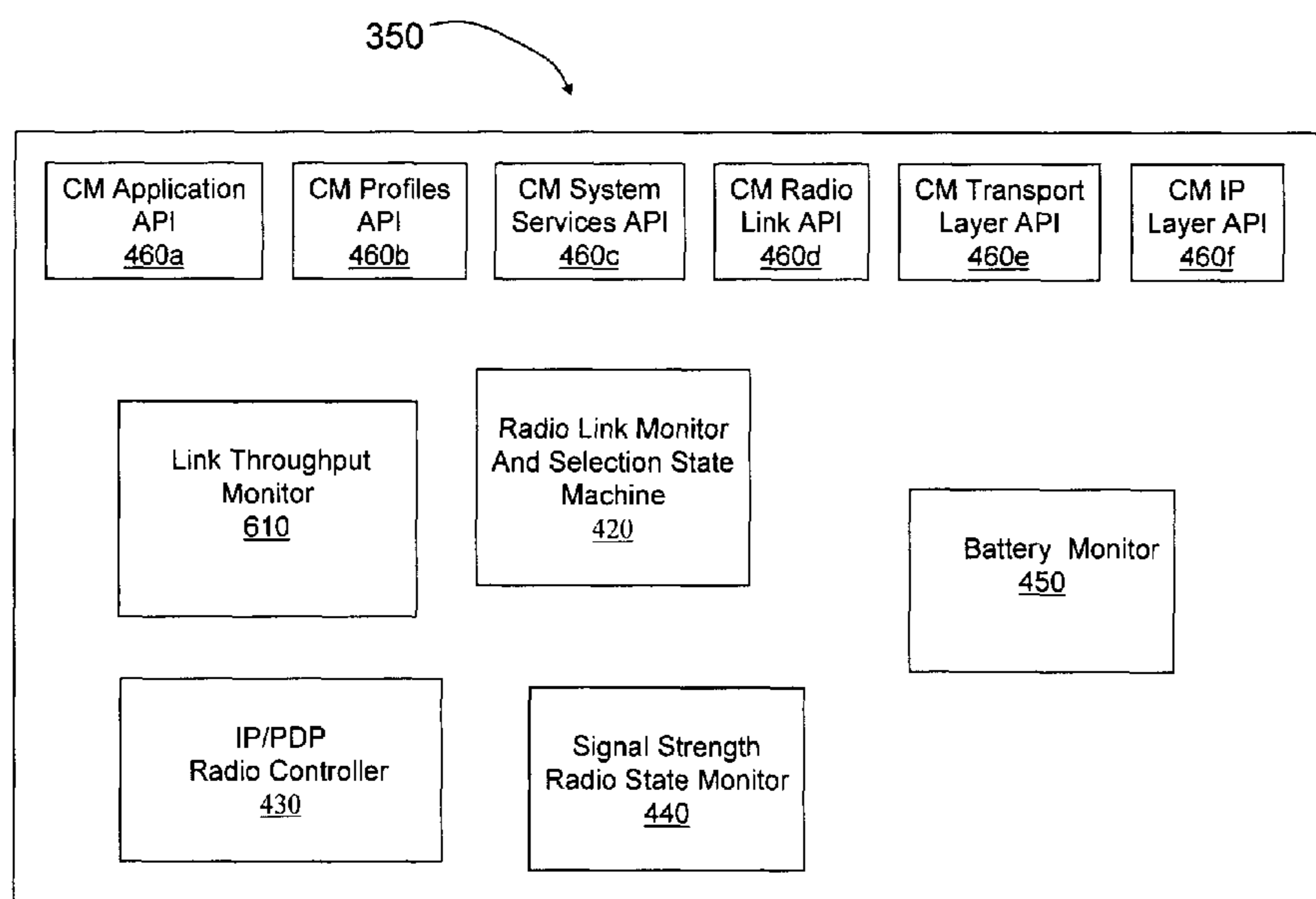


Figure 4

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| Operator Profile | IMS Service | Cellular Service | WLAN Service | WiMAX Service |
|---------------------------------------|-------------|------------------|--------------|---------------|
| Cellular Carrier | A | A | B (roam) | C (roam) |
| Cellular Carrier with WLAN | A | A | A | B (roam) |
| WiMAX Carrier | A | B (roam) | C (roam) | A |
| Carrier with all services except WLAN | A | A | B (roam) | A |
| Carrier with all services | A | A | A | A |

Figure 5

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| RSS | WLAN | WLAN | Cellular | WLAN | User/operator preference | WLAN |

Figure 6

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**SYSTEM, METHOD, AND
COMPUTER-READABLE MEDIUM FOR
USER EQUIPMENT DECISION-MAKING
CRITERIA FOR CONNECTIVITY AND
HANDOVER**

CROSS-REFERENCE

This patent application claims the benefit of provisional U.S. Patent Application Ser. No. 60/863,931, filed Nov. 1, 2006, which is hereby incorporated by reference. The following applications also claim priority to the above referenced provisional application and are related to the present application. They are incorporated by reference herein.

U.S. Utility patent application Ser. No. 11/929,066, which issued as U.S. Pat. No. 8,279,831 on Oct. 2, 2012, and was filed on Oct. 30, 2007 and entitled "System, Method, and Computer-Readable Medium for Selecting a Network for Connectivity and Handover Based on Application Requirements"

U.S. Utility patent application Ser. No. 11/929,376, which issued as U.S. Pat. No. 8,126,461 on Feb. 28, 2012, and was filed on Oct. 30, 2007 and entitled "System, Method, and Computer-Readable Medium for User Equipment Managing Multiple Radio Networks for Handover and Low-Power Operations"

BACKGROUND

IP multimedia subsystem (IMS) is a standardized architecture for provisioning of mobile and fixed multimedia systems. IMS provides for the transformation of the core wireless network architecture for efficient and cost-effective delivery of advanced multimedia services. Though driven by the 3rd Generation Partnership Project (3GPP), IMS is designed to be access agnostic—i.e., it enables access to advanced services via GSM, W-CDMA, CDMA2000, WiFi and other wireless broadband technologies like WiMAX, as well as fixed broadband systems. IMS aims to create a converged Internet Protocol (IP) infrastructure that allows key network resources to be shared by a wide range of services. IMS uses a voice-over-Internet Protocol (VoIP) scheme based on the standardized implementation of the session initiation protocol (SIP). The IMS standards define a network domain dedicated to the control and integration of multimedia services.

Without IMS, operators are forced to allocate dedicated components to each and every service that is deployed. Such service implementations are not scalable and are highly inefficient in a world in which users are demanding more personalized services and greater flexibility as regards to, for example, mixing and matching offerings. IMS also makes it possible for users to access multiple services in the course of the same call or session. Moreover, IMS enables operators to establish and control quality of service imperatives for individual services while at the same time protecting the overall integrity of network performance. IMS will significantly improve end-user experience by enabling flexible, personalized and seamless communications across access standards. A multi-mode, multi-radio user equipment is capable of obtaining services through multiple radio networks, for example, via a wireless wide area network (WWAN) such as GSM/UMTS and via a wireless local area network (WLAN) such as 802.11 a/b/g.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures, in which:

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FIG. 1 is a diagrammatic representation of an embodiment of a network system in which IMS may be deployed in accordance with an embodiment;

FIG. 2 depicts a diagrammatic representation of an embodiment of a multi-mode terminal;

FIG. 3 is a diagrammatic representation of an embodiment of a converged device configuration featuring a Convergence Manager that provides various connectivity and mobility features;

FIG. 4 is a diagrammatic representation of a convergence manager implemented in accordance with an embodiment;

FIG. 5 is a diagrammatic representation of an embodiment of a user subscription profile that depicts operator profiles of access network operators that may be used for connectivity/handover decisions; and

FIG. 6 is a diagrammatic representation of an embodiment of an operator rules profile that defines various services and corresponding preferred access networks.

DETAILED DESCRIPTION

It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

In accordance with an embodiment, a user equipment must decide on a particular network with which to attach, begin active services, and to which network it must handover its active services. For example, if the coverage of GSM/UMTS is poor in an office building, but the coverage of WLAN is good, the user equipment may choose to attach to the WLAN and also to receive incoming voice calls via the WLAN. In such a circumstance, the criteria used by the user equipment may be call quality and potential call quality. In a case where the user equipment chooses the GSM/UMTS network to attach and make outgoing calls, the criteria used by the user equipment may be power consumption and potential power consumption.

Some of the other criteria used by the user equipment may be a user profile that specifies one or more user preference connectivity attributes, available applications of the user equipment, a service subscription of a user associated with the user equipment, a battery monitor of the user equipment, a respective link metrics indicator for each of the plurality of access networks, and application support capabilities of the plurality of access networks as described more fully hereinbelow.

FIG. 1 is a diagrammatic representation of an embodiment of a network system **100** in which IMS may be deployed. FIG. 1 is intended as an example, and not as an architectural limitation, of embodiments described herein. IMS infrastructure may be deployed in stages and may include infrastructure developed and manufactured by a variety of vendors that may be deployed by any number of service carriers or operators. System **100** may include any variety of access networks. In the illustrative example, system **100** includes a wireless local area network (WLAN) **110**, e.g., a network implemented in compliance with the IEEE 802.11 standards, a packet switched universal mobile telecommunications system (UMTS) **120**, a circuit switched UMTS **130**, a public

switched telephone network (PSTN) **140** and corresponding signaling system **141**, such as a signaling system #7 network, and other IP access networks **150**. PSTN **140** provides circuit switched telecommunication services to one or more circuit switched end points **163**. WLAN **110** may interface with IMS **170** via WLAN access gateway (WAG) **111**. WLAN **110** may include a packet data gateway (PDG) **112**, one or more access points **113** that may provide wireless access to user equipments (UEs) **160-162**, and various other equipment as is understood. Packet UMTS **120** may include one or more gateway general packet radio service (GPRS) support nodes (GGSNs) and serving GPRS support nodes (SGSNs) (collectively referred to herein as G/SGSN **121**). Packet switched UMTS **120** may include a UMTS radio access network (UTRAN) **122** that may provide radio access to UEs **160-162** and various other equipment as is understood. WAG **111** comprises a gateway between WLAN **110** and 3GPP/IMS network **100**. A Packet Data Gateway (PDG) **112** provides access to PS-based services for a WLAN UE. Circuit UMTS **130** may include a mobile services switching center (MSC) **131**, a UTRAN **132**, and various other equipment as is understood.

Various terminals may connect with one or more of the access networks. As referred to herein, a user equipment (UE) comprises a terminal or station that may connect with one or more access networks for establishing a session with an entity of system **100** or another user equipment or terminal connected with one or more of the access networks of system **100** or another telecommunication system. In the depicted example, UE **160** is connected with WLAN **110**, UE **161** is connected with packet UMTS **120**, and UE **162** is connected with circuit UMTS **130**. Additionally, an analog endpoint **163**, such as an analog telephone, is connected with PSTN **140**. Some UEs may be adapted to connect, in some instances concurrently, with multiple access networks. A UE adapted to connect with multiple access networks is referred to herein as a multi-mode UE or device.

IMS **170** may include various functions, nodes, or other entities, and those depicted in FIG. **1** are illustrated to facilitate an understanding of embodiments disclosed herein. Call Session Control Function (CSCF) **171** may act as Proxy CSCF (P-CSCF), Serving CSCF (S-CSCF) or Interrogating CSCF (I-CSCF).

SIP may be used as the protocol for communications between a UE with CSCF **171**. A Media Gateway Control Function (MGCF) **172** controls the parts of the call state that pertain to connection control for media channels in an IMS-media gateway (MGW), e.g., MGW **173**. MGCF **172** may communicate with CSCF **171**, a breakout gateway control function (BGCF), e.g., a SIP server that includes routing functionality based on telephone numbers, and PSTN **140** entities. Additionally, MGCF **172** may determine the next hop depending on the routing number for incoming calls from legacy networks. MGCF **172** may include or interface with a media gateway controller (MGC) **174** and a signaling gateway **176**.

IMS-MGW **173** may terminate bearer channels from a circuit switched network, e.g., PSTN **140**, and media streams, e.g., RTP streams in an IP network, from a packet network, e.g., packet UMTS **120**. IMS-MGW **173** may support media conversion, bearer control and payload processing, e.g. codec, echo canceller, conference bridging, and the like. IMS-MGW **173** may interact with MGCF **172** for resource control, own and handle resources such as echo cancellers, etc, and may be equipped with codecs.

A Multimedia Resource Function Controller (MRFC) **182** may control media stream resources in a Multimedia

Resource Function Processor (MRFP) **180**, interpret information coming from an application server (AS) **186** and S-CSCF, e.g., a session identifier, and control MRFP **180** accordingly.

MRFP **180** may control IP bearers, provide resources to be controlled by MRFC **182**, mix incoming media streams, e.g., for multiple parties, sources media streams (for multimedia announcements), and process media streams, e.g., audio transcoding, media analysis, and the like, and perform floor control, i.e., manage access rights to shared resources in a conferencing environment.

Application Server **186**, e.g., a SIP Application Server, OSA Application Server, CAMEL IM-SSF application server, or other application server, may offer value added services to system **100** and reside either in the user's home network or in a third party location. The third party could be a network or simply a stand-alone AS. Application Server **186** may influence and impact a SIP session on behalf of the services supported by the operator's network. An AS may host and execute services.

IMS functioning is access network agnostic. However, the connectivity of each access network to the IMS infrastructure is specific to the access network.

Voice Call Continuity (VCC) from circuit UMTS **130** to IMS **170** (VoIP over IMS) is being specified in 3GPP. Two logical functions, a Call Continuity Control Function (CCCF) and Network Domain Selection (NeDS), are added to the architecture to support VCC.

The Call Continuity Control Function provides for reception and processing of call continuity requests caused by radio related events, e.g., availability or loss of radio coverage, and establishment and release of call legs needed to transfer a voice call from the CS domain to the IMS domain, or vice versa.

Network Domain Selection (NeDS) comprises the control point for selecting which domain to use for terminating a call. Normally it may be expected that a CS terminating call will terminate on the CS side of a multi-mode terminal, and an IMS terminating call will terminate on the IMS side of a multi-mode terminal, although there are situations where the selection of the other domain is appropriate, e.g., in the case of a CS terminating call when the terminal is not CS-attached but is IMS registered. In addition to technical considerations, user preferences and service availability considerations may be considered and may be implemented in the NeDS function. The UE may be registered to both domains and may choose to originate a voice call (or session) via either CS or IMS domain, depending on operator offered choices.

Exemplary applications and services that may be supported by IMS **170** include web browsing, video sharing, video telephony and conferencing, push to talk over cellular, presence services, instant messaging, multiplayer games, and concurrent IMS services and CS voice services.

For the specific case of multimode convergence based on IMS, there are certain user scenarios that require management of the multiple access systems supported by the handset. Some of these scenarios include:

- Support of multiple connections via multiple access standards e.g., video sharing via cellular and background email download via WLAN or WiMax;

- Handling a second incoming call via another access standard;

- Handover and mobility of data sessions and VoIP calls; and Emergency call via best access standard.

As IMS infrastructure and service deployment progresses, handset vendors continue to face the same challenges that have been driving them over the past several years, e.g., the

capability to offer new services and features in the handset without increasing cost of the handset, handset development cost, and time to market the handset.

Converged or convergence terminals, i.e., UEs compatible with IMS **170**, have in many ways already taken root. However, while converged terminals have opened doors to the promise of multiple utility terminals, many existing devices are still somewhat service specific. The best examples currently are the camera phone and RIM BlackBerry™. Despite these current concerns and shortcomings, converged devices provide the promise of reaching the goal of one device that holds functionality for all forms of communications, computing, music, video, games, and personal efficiency.

To be suitably adapted to interface with various access networks, a converged terminal may be adapted to multiple modems. To accommodate multi-radio terminals for interfacing with multi-access networks, a converged terminal essentially needs multi-access awareness. A multi-radio device needs to be able to access different services through different access methods. Being able to access email via WLAN or GPRS from a smart phone, playing a game over Bluetooth with a friend in the same room and then inviting a far-away friend to join the game via 3G are examples of what activities are possible via IMS **170**.

Management of handset resources is critical for a desirable user-experience in IMS **170**. Because of the variety of applications that may be run via IMS **170**, energy consumption can be expected to increase as additional applications and more processor-intensive services are deployed. However, improvements in battery capacity simply haven't kept pace with ever-more-powerful processors and other power consumers in the handset. Accordingly, efficient management of power consumption mechanisms are provided by embodiments disclosed herein.

With the addition of new features and services, handset development costs and time to market continue to be important factors in UE design. Modular designs that feature various sub-systems that may be obtained from a variety of vendors may advantageously reduce handset development costs.

With reference now to FIG. 2, an exemplary software configuration **200** of a converged terminal is depicted. Various applications **210** may be deployed in configuration **200**. In the illustrative example, applications **210** include an Email application **210a**, a browser application **210b**, a VoIP application **210c**, and a circuit-switched application **210d**. Applications **210** are bound to application layer **220**, e.g., via traditional sockets and ports as shown in FIG. 2. In the illustrative example, application layer **220** includes SIP **220a**, SDP **220b**, and RTC/RTCP **220c**.

SIP **220a** is an application layer protocol. Session Initiation Protocol (SIP) was developed and designed within the Internet Engineering Task Force (IETF). SIP is a request-response signaling protocol for setting up and starting voice, video, and instant messaging communication sessions over the Internet.

SIP's essential communication function is aided by extensions and further protocols and standards. Two protocols commonly used are the Session Description Protocol (SDP) **220b** and Real-time Transport protocol **220c** (RTP).

RTP **220c** is used to carry session payload data, such as real-time multimedia data such as audio, video, and text. RTP **220c** encodes and splits the data into packets and transports such packets over the Internet. RTP **220c** is frequently used in streaming media systems as well as videoconferencing and push to talk systems making it the technical foundation of the Voice over IP industry. RTP may be used in conjunction with the RTP Control Protocol (RTCP) and it is built on top of the User Datagram Protocol (UDP).

SDP **220b** describes and encodes capabilities of session participants. Such a description is then used to negotiate the characteristics of the session so that all devices can participate. Hence, SIP, SDP, and RTP/RTCP are necessary to implement an application such as a "SIP-based VoIP" protocol.

Application layer **210** may interface with lower layers of network stack **230**. In the illustrative example, network stack **230** includes a transmission control protocol (TCP) **231a** and a user datagram protocol (UDP) **231b** transport layers, an IP security (IPSec) **232** layer, and an IP **233** network layer, although other transport and network layers may be suitably substituted for those depicted.

Convergent terminals require the support of multiple protocol stacks **240** and **241** and multiple radios as shown in FIG. 2. The first impact is on the hardware that requires integration of the modem basebands onto the same system. In typical designs, the basebands of the various modems are implemented on different chips. Additionally, a converged device may feature the co-existence and simultaneous activity of multiple radios. The multiple modems need to be able to communicate with upper layers (typically IP) via identifiers such as the UMTS PDP contexts **250a-250c** (illustratively designated with dashed lines) shown in FIG. 2. Each primary PDP context **250a** is associated with a unique PDP address (which includes the IP address) and each secondary PDP context **250b-250c** is associated with a primary context and helps support multiple QoS streams required by different applications supported in lower layers via different radio access bearers. Major cellular standards as well as emerging wireless broadband standards, such as WiMax, support well defined QoS classes. In the illustrative example, configuration **200** includes a first protocol stack **240** adapted to accommodate UMTS access and includes a cellular radio interface **240a**, a UMTS non-access stratum **240b**, and a UMTS access stratum **240c**. A second protocol stack **241** adapted to accommodate wireless radio broadband access network may include a wireless broadband radio interface **241a** and a wireless broadband protocol stack **241b**, e.g., a wireless broadband physical (PHY) layer, media access control (MAC) layer, security and CSL layers, or the like.

Additionally, a converged device may feature a High level OS (HLOS), such as Symbian, Linux, and Microsoft Windows Mobile. HLOS vendors or associated groups, such as Mobilinux Open Framework, are offering more integrated features in their software packages such as IPv6, 2.5G and 3G radio interface layers and connectivity management software.

In accordance with embodiments disclosed herein, a Convergence Manager (CM) provides connectivity management and, among other services, mobility across various network standards. The CM provides for multimode mobility management and multimode data plane management within the CM and facilitates cellular plus wireless broadband terminal convergence, including service continuity and handoff between cellular and wireless broadband.

FIG. 3 is a diagrammatic representation of an embodiment of a converged device configuration **300** featuring a Convergence Manager (CM) **350** that provides various connectivity and mobility features.

CM **350** interfaces with multiple access entities, such as 802.16 access entity **310**, 802.11 access entity **311**, and UMTS access entity **312**. 802.16 access entity **310** includes a physical (PHY) layer **310a**, a media access and control (MAC) layer **310b**, and a service specific convergence layer **310c**. 802.11 entity **311** includes a PHY layer **311a**, MAC layer **311b**, and management entities **311c**. UMTS entity **312** includes a radio link controller (RLC)/MAC/PHY layer **312a**,

a radio resource control (RRC) layer **312b**, UMTS Non-Access stratum **312c**, and radio interface **312d**. Access entities **310-312** may be communicatively coupled with radio access interface **320** that interfaces with upper layers, such as a network stack **330** and convergence manager **350**. Network stack **330** may include a network layer, such as IP layer **330a**, an IP security layer (IPSec) **330b**, a transport layer, such as user datagram protocol (UDP) layer **330c** or transmission control protocol (TCP) layer **330d**. Network stack **330** and convergence manager **350** may interface with an application layer **340** via an application interface **360**.

CM **350** may support multimode network and cell selection. CM **350** may be adapted to perform access network data collection including network scan and cell measurements optimized for low terminal power consumption. At power on, as per mode settings, CM **350** may scan for wireless broadband and cellular coverage and decide the best network to camp on.

CM **350** may feature operator and user customizable threshold and profiles. To this end, CM **350** may be adapted to receive as input a customizable set of operational thresholds, such as signal strength, power, call quality, etc., and user/operator profiles, rules for scan, network-selection, handover, etc., that will govern network selection and handover decisions between multiple access modes.

CM **350** may be adapted to perform periodic and event driven evaluation of connections and handover decisions. CM **350** may analyze the access data it collects from various protocol stacks, e.g., protocol stacks included in 802.16 entity **310**, an 802.11 stack included in 802.11 entity **311**, and a UMTS stack included in a UMTS entity **312**, as well as to take into account the rules and profiles provided by the user or operators. Based on this information, CM **350** may make a connectivity or handover decision and communicate with the appropriate software entities for handover execution.

Entities **310-312** may interface with radio access interface **320** and network/transport stack layers **330**. Various applications may be deployed at application layer **340**, such as a SIP application **340a**, an HTTP application **340b**, a VoIP/RTP application **340c**, a circuit-switched application **340d**, such as a voice application, and may be bound to lower stack layers via application interface **360**. Other applications that may be included in converged device configuration **300** may include an instant messaging (IM) application, a presence application, or any other suitable application that may be run by a user equipment.

CM **350** may be adapted to provide feedback to a network operator and/or end-user. CM **350** may provide feedback of results of its analysis of multimode access conditions and decisions to the operator, and in certain cases to the user. For example, operational feedback provided to the end-user may be provided via the handset application UI **360**.

CM **350** may provide management of multiple access connections. To this end, CM **350** may allow and manage connections to multiple access networks simultaneously depending upon handset use cases supported. For example, voice call via cellular services may be provided while email is downloading via WLAN.

CM **350** may provide data session continuity. To this end, CM **350** may provide data session continuity as the user roams from coverage area of one mode to another if CM **350** decides based on its thresholds/rules/profiles that it is appropriate to move the connection from one access mode to another.

CM **350** may facilitate VoIP handover. For example, CM **350** may provide support for handover of VoIP calls from one access mode to another with the assumption that VoIP is

supported over both cellular and wireless broadband access modes. Additionally, CM **350** may manage voice handover to/from a packet-switched access mode from/to a circuit-switched access mode.

CM **350** may support Voice Call Continuity (VCC). CM **350** may support continuity of a voice call from cellular circuit switched domain to VoIP over IMS over wireless broadband as specified by 3GPP.

CM **350** is preferably implemented to be compliant to all related 3GPP specifications, e.g., IMS, 3G-WLAN, VCC as well as aligned to the IEEE 802.21 Media Independent Handover.

CM **350** may provide inter-system data session continuity and voice handover between cellular and wireless broadband modes. CM **350** preferably allows mobility across multiple modes with the decision to handover taken based on a variety of parameters that operators and end users' preferences. The handover decision logic will be such that any ping-pong effect is minimized and the decision is optimized to use the connection best suited for the service. CM **350** may feature connection/handover decisions that advantageously minimize handset power consumption, provide a desired call quality, as well as provide the user the most cost effective service at any time thereby enabling a richer user experience. Moreover, CM **350** may make context driven connection decisions. For example, emergency calls may be initiated via the most robust connections available at any time.

CM **350** may allow operators to customize the rules governing connection and handover decisions. For example, an operator may decide that the UE must initiate all emergency calls via the cellular network, or that if the UE is within a WLAN coverage area any web browsing session must be initiated via the WLAN network. This feature may be associated with a default set of rules for easy usage but may also give maximum configurability to operators based on the operators' network design and business needs.

FIG. 4 is a diagrammatic representation of CM **350** implemented in accordance with an embodiment. Convergence manager **350** manages connectivity to an access network based on access cost, access network availability, and the particular application(s) (among other considerations) to be run on the converged device. CM **350** provides a convergence solution that features seamless handover and auto-connectivity across cellular and wireless broadband networks to provide "always-on" connection to the Internet and voice based services. Connection management and handover decisions may be based on periodic and/or event driven decisions. CM **350** provides a unique connectivity and handover management for terminal-based access network selection. CM **350** facilitates efficient management of simultaneous connections to different access networks, e.g., voice over cellular and email over WLAN. Moreover, CM **350** provides low latency start up and incoming calls providing seamless continuity of real time services, e.g., voice between cellular and wireless broadband coverage. Additionally, CM **350** provides access to emergency services, power management of multimode activities.

CM **350** may facilitate multimode network scan to facilitate terminal-based connectivity decisions. Additionally, CM **350** provides multimode mobility handling across wireless broadband and cellular, simultaneous wireless broadband and cellular connection management, power management of multimode activities, e.g., smart network scan and measurement, operator and user customizable rules for connectivity and roaming, voice call continuity (e.g., handover), and data session continuity. End-user benefits of CM **350** include unified access convergence management for multi-radio handsets,

access and application aware decisions of best or most desirable connectivity, unified connectivity interface to network (e.g., TCP/IP) and session management (e.g., SIP/SDP) layers, multimode mobility handling across WiBro/WiMax, Cellular, WLAN, or other access networks.

CM 350 may be implemented as a group of software modules deployed on the UE that make decisions regarding what is the best or preferable access system for establishing connectivity to the wired (cable, DSL, etc.) or wireless (WLAN, WiMax, cellular such as GSM/GPRS, CDMA, UMTS, etc.) network infrastructure as well as when to handover the connectivity from one access system to another. Connectivity management and handover decisions may be made based on rules configured by the service provider(s) and/or end-user preferences, a user profile based on expected usage, user profile based on service subscriptions, requirements of specific applications—both circuit switched and packet switched—environmental conditions such as signal strengths of each access network, and user equipment power conditions.

In addition, CM 350 provides a transparent network layer to the upper layers. CM 350 offers IP/PDP context control, including activation, modification, and de-activation. In this way, CM 350 hides lower layer details, both functional and implementation specific, from the upper layers, and provides a complete IP layer platform for the upper layers.

CM 350 may include a link throughput monitor 410 to measure the throughput of links between the host UE and access networks. CM 350 may include a radio link monitor and selection state machine 420 that facilitates evaluation of link metrics and access network selection. Additionally, CM 350 may include an IP/PDP radio controller 430 and a signal strength radio state monitor 440. A battery monitor 450 may be included to monitor battery usage/capacity of the host UE battery.

CM 350 may include or interface with various application programming interfaces (APIs). In the illustrative example, CM 350 includes an application API 460a, a CM profiles API 460b, a CM system services API 460c, a CM Radio Link API 460d, a CM transport layer API 460e, and a CM IP layer API 460f.

CM 350 may manage AT commands to the mobile terminal (MT), interfaces between VCC applications and the MT, register with cellular networks, manage WLAN layer 1 (L1)/layer 2 (L2) to be ready for communications, monitor radio quality and inform VCC application(s) of radio quality status, and trigger fast handover from/to GSM/WLAN.

CM Application API 460a may feature an open/close socket function used to open a socket with QoS parameters on a particular host IP. IP/PDP activation is preferably made when the open command is made. For wireless broadband, an open socket command may be made before IP is available. In this case, an implicit IP activation procedure may take place.

CM Application API 460a may feature an IP/PDP activation/modification function including one or more of an explicit activation/modification function, an implicit activation/modification function, and an automatic activation/modification function. An explicit activation/modification function is activated directly by upper layers, while an implicit activation/modification function is activated when a socket open request is made. An automatic activation/modification function may provide an indirect activation by the upper layers that, for example, direct CM 350 to activate the IP/PDP with QoS appropriate for IMS activation when a new access network is detected.

A radio link state status request/Indicator function may be used to check on the status of the radio link. For example, PDP

context information such as QoS, IP address, Radio link state (PDP context state, P/S attached, etc.) may be obtained.

A radio link selection request/Indicator function based on priority parameters or profiles may be used to query which radio link should be used for a particular application. The radio link selection request function may be application dependent because each application may have different criteria for radio link selection. Radio link selection priorities may be based on the default profile database or passed to the radio link selection request function as parameters. The Indicator can also be event triggered and can signal to the IMS services that a change of domain should be made for a certain application or for all applications. This request/Indicator is serviced by the main decision maker that determines which applications should be mapped to which radio link and when.

Link event triggers may include upper layer trigger events, such as time to register, time to handover, time to establish IP/PDP context, and link layer events, such as link lost or weak link, and manual switch events.

In accordance with another embodiment, UE-based inter-access-mode connectivity and handover decisions may be made by CM 350. Decisions may be made in a UE regarding what is the best access system for establishing connectivity to the wired (cable, DSL, etc) or wireless (WLAN, WiMax, cellular such as GSM/GPRS, CDMA, UMTS, etc) network infrastructure as well as when to handover the connectivity from one access system to another. This decision may be made based on rules configured by the service provider(s), user profile based on expected usage, user profile based on service subscriptions, requirements of specific applications—both circuit switched and packet switched based, and environmental conditions such as signal strengths of each network, and user equipment power conditions.

Inter-access-mode connectivity and handover decisions may be made based on various sources of input information including a set of rules provided by the service provider, user profile based on usage, user profile based on service subscriptions, profile of applications supported by the UE, battery monitor in the UE, signal strength indicator of each access system as seen by the UE, and applications supported by the available access systems. A set of rules provided by the service provider may include, for example, a requirement to always make emergency calls via a cellular access network whenever a cellular access network is available, a requirement for voice calls to always be made using VoIP over WLAN if WLAN connectivity is available, and alternatively to use a cellular access network in the event that WLAN connectivity is not available. User profile based on usage rules may include, for example, prioritization of user concerns, such as cost, power consumption, low latency for service start up, low latency for receiving calls/email/IM/data, continuity of real time services, sense of always connected for non-real time services, availability of emergency services, and the like.

Rules based on user profile service subscriptions may evaluate whether single or multiple providers are associated with various available access systems.

A battery monitor in the UE may also be used for connectivity/handover decisions. For example, if a battery capacity falls below a particular threshold, preference may be assigned to a lower power retirement access network. A signal strength indicator of each access system as seen by the UE may be based on network scanning and measurement. In an embodiment, the connectivity and handover decisions are made by CM 350.

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Periodically the handover decision entity in the UE executes the following steps:

- collect network strength indications from each of the radios; and
- collect battery information from battery monitor.

The UE may execute the following steps for connectivity/handover when certain “events” occur. Exemplary events include:

Battery power below a certain threshold: An action for this event may be switching off all radios except cellular and shutting down all applications except any on-going cellular voice call.

Battery drain above a certain threshold: switch to the network that uses lower power for the current application.

Signal strength of a certain network goes above a certain threshold. An action for this event may be adding this network as part of the periodic decision process.

FIG. 5 is a diagrammatic representation of a user subscription profile 500 that depicts operator profiles of access network operators (designated “A”, “B”, and “C”; where “A” indicates service provided by the home carrier’s network(s), and “B”, “C” are services provided by another network operator/carrier, hence marked “roam”) that may be used for connectivity/handover decisions. CM 350 may evaluate profile 700 to evaluate the operator service offerings, e.g., IMS, cellular, WLAN, WiMAX, and the like.

FIG. 6 is a diagrammatic representation of an embodiment of an operator rules profile 600 that defines various services, e.g., emergency call, VoIP, presence, and other services, and corresponding preferred access networks. In the illustrative example, a preferred access network may be dependent on a relative quality assessment of an access network. For instance, if both WLAN and cellular access network qualities, e.g., signal strengths, throughput, or other metric, are evaluated as “good,” preference may be assigned to the cellular access network for an emergency call service. However, if the cellular access network quality is evaluated as bad, preference may be assigned to WLAN for performing an emergency call service. In accordance with another embodiment, mechanisms for inter-system monitoring and connection state management for multi-mode networks and terminals are provided. Advantages of mechanisms disclosed herein provide for low power consumption, preparation for quick, seamless handovers, and an “always on” environment in the terminal.

Consider the following Scenario: Switch from WLAN to Cellular

In this scenario, no real time service is active at this point. The CM senses that the WLAN network is getting weak, or possibly already out of service, and services need to be transferred to Cellular.

In the selection to determine which radio network should be primary and which secondary, the following exemplary parameters may be evaluated:

- cost
- power
- coverage/signal strength/call quality
- connectivity/application priority (emergency call, real time service, non-real time service, best effort, etc.)
- service provider’s preferences
- user’s preferences

If power is an issue, the WWAN or cellular network may be designated for preference for always on applications if cellular provides better standby time.

User preferences may be assigned to any one or more of the following exemplary considerations:

- Total cost
- Standby and talk time

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- Low latency for service start up
- Low latency for receiving calls, email, IM, and data
- Call Quality
- Continuity of real time services
- sense of always connected for non-real time services
- availability of emergency services
- Ease of use

Connectivity and handover may be user-optimized based on the user preferences.

As described, mechanisms providing for decision-making criteria in a multi-mode, multi-radio user equipment to choose which radio network to use for connectivity and handover are provided. Decision making depends on a number of different criteria: a user profile that specifies one or more user preference connectivity attributes, available applications of the user equipment, a service subscription of a user associated with the user equipment, a battery monitor of the user equipment, a respective link metrics indicator for each of the plurality of access networks, and application support capabilities of the plurality of access networks.

The illustrative block diagrams depict process steps or blocks that may represent modules, segments, or portions of code that include one or more executable instructions for implementing specific logical functions or steps in the process. Although the particular examples illustrate specific process steps or procedures, many alternative implementations are possible and may be made by simple design choice. Some process steps may be executed in different order from the specific description herein based on, for example, considerations of function, purpose, conformance to standard, legacy structure, user interface design, and the like.

Aspects of disclosed embodiments may be implemented in software, hardware, firmware, or a combination thereof. The various elements of the system, either individually or in combination, may be implemented as a computer program product tangibly embodied in a machine-readable storage device for execution by a processing unit. Various steps of embodiments may be performed by a computer processor executing a program tangibly embodied on a computer-readable medium to perform functions by operating on input and generating output. The computer-readable medium may be, for example, a memory, a transportable medium such as a compact disk, a floppy disk, or a diskette, such that a computer program embodying the aspects of the present invention can be loaded onto a computer. The computer program is not limited to any particular embodiment, and may, for example, be implemented in an operating system, application program, foreground or background process, driver, network stack, or any combination thereof, executing on a single computer processor or multiple computer processors. Additionally, various steps of embodiments may provide one or more data structures generated, produced, received, or otherwise implemented on a computer-readable medium, such as a memory.

Although embodiments of the present disclosure have been described in detail, those skilled in the art should understand that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure. For example, descriptions of a UE convergence manager have been provided in the context of a UE deployed in a network system featuring IMS. However, such a network system is not necessary, but rather advantages may be had by implementation of embodiments disclosed herein in any multi-mode network system that features multiple access network technologies with or without IMS. Accordingly, all such changes, substitutions and alterations are intended to be included within the scope of the present disclosure as defined in the following claims.

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What is claimed is:

1. A method of selecting an access network by a wireless user equipment for provisioning of communication services, comprising:

performing, at a convergence manager in the wireless user equipment, an evaluation of each of:

a battery monitor that includes a strength of a battery in the user equipment;

connectivity rules provided to the wireless user equipment from a network entity related to one or more of a plurality of access networks;

connectivity rules provided to the wireless user equipment by a service provider related to one or more of the plurality of access networks;

a user profile that specifies one or more user preference connectivity attributes selected by the user; available applications of the wireless user equipment;

a respective link metrics indicator for each of the plurality of access networks; and

application support capabilities of the plurality of access networks; and

selecting, at the convergence manager in the wireless user equipment, the access network from the access networks based on results of the evaluation,

performing a handover of the wireless user equipment to the access network selected at the convergence manager from another access network;

wherein selection of the access network is performed by the user equipment for beginning active services with the selected access network or handover active services from another access network to the selected access network;

determining that a battery level of the battery is below a predetermined threshold; and

in response to determining that the battery is below a predetermined threshold, powering off all radios except those in connection with the access network, and further including shutting down all applications except any ongoing cellular voice call.

2. The method of claim 1, wherein the battery monitor further includes a battery voltage and an estimated current drain based on any applications running on the user equipment.

3. The method of claim 1, wherein selection of the access network is performed for attachment of the user equipment to the selected access network.

4. The method of claim 1, wherein the evaluation is further performed based on one or more of, a standby time, a talk time, a total cost, a low latency for service start up attribute, a low latency for receiving calls attribute, email availability, an instant messenger availability, a data service availability, a continuity of real time services availability, a sense of always connected for non-real time services attribute, availability of emergency services, and an ease of use attribute.

5. A system of selecting an access network, comprising:

a plurality of access networks including a first access network operating in conjunction with a first radio access technology and a second access network operating in conjunction with a second radio access technology;

a wireless user equipment able to selectively terminate at least one of a first communication link with a first access network and a second communication link with a second access network, the first access network capable of operating in conjunction with a first radio access technology, and the second access network capable of operating in conjunction with a second radio access technology;

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wherein the wireless user equipment includes a convergence manager that performs an evaluation of each of: a battery monitor that includes a strength of a battery in the user equipment;

connectivity rules provided to the wireless user equipment from a network entity related to one or more of a plurality of access networks;

connectivity rules provided to the wireless user equipment by a service provider related to one or more of the plurality of access networks;

a user profile that specifies one or more user preference connectivity attributes selected by the user;

available applications of the wireless user equipment;

a respective link metrics indicator for each of the plurality of access networks; and

application support capabilities of the plurality of access networks;

wherein the convergence manager is configured to select the access network from the access networks based on results of the evaluation,

wherein selection of the access network is performed for beginning active services with the selected access network or handover active services from another access network to the selected access network; and

determining that a battery level of the battery is below a predetermined threshold; and

in response to determining that the battery is below a predetermined threshold, powering off all radios except those in connection with the access network, and further including shutting down all applications except any ongoing cellular voice call.

6. The system of claim 5, wherein the battery monitor further includes evaluation of at least one of a battery strength, voltage, and estimated current drain based on any applications running on the user equipment.

7. The system of claim 5, wherein selection of the access network is performed for attachment of the user equipment to the selected access network.

8. The system of claim 5, wherein the evaluation is performed further based on at least one of a standby time, a talk time, a total cost, a low latency for service start up attribute, a low latency for receiving calls attribute, email availability, an instant messenger availability, a data service availability, a continuity of real time services availability, a sense of always connected for non-real time services attribute, availability of emergency services, and an ease of use attribute.

9. A multi-mode user equipment, comprising:

a first modem able to transmit data to a first access network and receive data from the first access network;

a second modem able to transmit data to a second access network and receive data from the second access network;

a first software stack compliant with the first access network;

a second software stack compliant with the second access network; and

a convergence manager configured to perform an evaluation of each of:

a battery monitor that includes a strength of a battery in the user equipment;

connectivity rules provided to the wireless user equipment from a network entity related to one or more of a plurality of access networks;

connectivity rules provided to the wireless user equipment by a service provider related to one or more of the plurality of access networks;

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a user profile that specifies one or more user preference connectivity attributes selected by the user; available applications of the wireless user equipment; a respective link metrics indicator for each of the plurality of access networks; and application support capabilities of the plurality of access networks;

wherein the user equipment is able to select one of the access networks for connectivity and handover based on results of the evaluation, wherein selection of the access network at the convergence manager enables beginning active services with the selected access network or handover of active services from another access network to the selected access network; and

determining that a battery level of the battery is below a predetermined threshold; and

in response to determining that the battery is below a predetermined threshold, powering off all radios except those in connection with the access network, and further including shutting down all applications except any ongoing cellular voice call.

10. The user equipment of claim 9, wherein the user equipment is further able to select an access network for handover of the user equipment based on one or more of: the rules configured by the service provider, the requirements of applications hosted by the user equipment, and environmental conditions.

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11. The user equipment of claim 9, wherein the user equipment is further able to receive a set of rules provided by the service provider to perform a connectivity evaluation.

12. The user equipment of claim 9, wherein the user equipment is further able to receive a user profile based on usage as input to perform a connectivity evaluation.

13. The user equipment of claim 9, wherein the user equipment is further able to receive a user profile based on service subscriptions to perform a connectivity evaluation.

14. The user equipment of claim 9, wherein user equipment is further able to receive a profile of applications supported by the user equipment to perform a connectivity evaluation.

15. The user equipment of claim 9, wherein user equipment is further able to receive a signal strength indicator of the first access network and the second access network to perform a connectivity evaluation.

16. The method of claim 1, including determining that a signal strength of a certain access network is above a certain threshold, the method further including adding the certain access network to the plurality of access networks.

17. The method of claim 1, further including: identifying an application executing on the wireless user equipment, wherein performing a handover of the wireless user equipment to the access network selected at the convergence manager from another access is done in response to opening or closing the application.

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